ANALYSIS OF HYPERSPECTRAL DATA OF COTTON TO ESTIMATE VEGETATION INDICES UNDER DIFFERENT SOIL FERTILITY RATE

Analisis Data Hyperspectral Tanaman Kapas untuk Mengistimasi Indeks Vegetasi pada Tingkat Kesuburan Tanah yang Berbeda

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ABSTRAK

Kesuburan tanah sangat penting untuk pertumbuhan kapas. Status kesuburan tanah akan mempengaruhi dosis pemupukan pada tanah. Distribusi spasial kesuburan tanah dilapangan akan mempengaruhi produktifitas. Oleh karena itu, data laboratorium pengindraan jauh dapat digunakan untuk mendeteksi dan menganalisis kesuburan tanah yang mempengaruhi pertumbuhan kapas. Tujuan penelitian ini adalah untuk menunjukkan bahwa pengukuran data hyperspectral dapat memberikan petunjuk perbedaan pertumbuhan pada tingkat kesuburan tanah yang berbeda dengan melakukan analisa index tanaman. Spetraradiometer didisain untuk mengoleksi septrum tanaman dibawah tingkat kesuburan tanah yang berbeda telah diuji cobakan. Beberapa rumus index tanaman digunakan dalam penelitian ini.

Kata kunci: tingkat kesuburan tanah, spektroradiometer, hyperspectral, spectrum tanaman kapas.

INTRODUCTION

During the past several decades, the tools for vegetation remote sensing have evolved significantly (Asner, 1998). Remote sensing has become one of main tools for agricultural application especially for crops monitoring during growth cycle using vegetation indices as indicators (clevers and jongschap, 2003). Remotely sensed reflectance data, obtained by devise, satellite or aircraft, can provide at relatively low cost a set of detailed, spatially distributed data on plant growth and development. Such data may form a useful component of site-specific crop management programs (moran et al, 1997, senay et al, 1998). Meanwhile, growth of agricultural crops may not be optimal as a result of stresses due to fertilizer deficience, pest and disease incidence, and drought of frost (clevers 1999). Early detection of vegetation stress of agricultural crops ca be estimated by using vegetation indices values derive from remote sensing data.

One factor that affect crop stress, the fertility, is a prerequisite for their production potential Without fertilizer production potential can decrease significantly. Therefore fertilizer is crucial factor to be added in crop farming practices. Fertilizer deficiency in the field can result crop stress. Likewise, stress may cause biophysical changes in canopy structure, coverage, leaf area index or biomass. Essentially, alterations of leaf chemistry also may bc used to detect subtle changes in the vitality or vigor of vegetation (Clevers 1999) Until now most promising results obtained from remote sensing data for detccting the occurrence of plant stress decrease in vitality are obtained by studying the sharp rise in spectral reflectance of green vegetation between 670 and 780 nanometers (nm). In addition, other regions of electromagnetic reflectance data such as green (roughly 500-600 nm). red (roughly 600-700 nm) and near infrared (roughly 700-900 nm) bands are generally expresséd in the form of vegetation indices, which are algcbraic combinations of the measured canopy reflectance of different wavelength bands Many of these indices are algebraically related (Perry & Lautenschlager 1984)

One of the reflectance range of green vegetation between 670 and 780, called the red-edge has become intensive study for vegetation performance. Both the position and the slope of the red-edge change under stress conditions, resulting unto a bluc shift of the red-edge position The position of the red-edge is defined as the position of the main inflexion point of the red infrared slope. This is called the red-edge index. Reliable detection of this index requires sampling at about 10 nanometer intervals or less, requiring high-resolution spectral measurements Crop canopy reflectance in this red and near infrared regions of the electromagnetic spectrum provides a means of estimating the photosynthetic status of the crop (Sellers 1989). This red- infrared value can be calculated and expressed as red-edge ratio (Gitelson & Merzylak, 1996). Vegetation indexes such as Chlorophyll-Absorption Integral (CAI) index (Oppeit & Mauser 200la & 2001b). Normalised-Difference Vegetation Index (NDVI) (Tucker 1979) and Nitrogen Vegetation Index (NVI) (Takebe er al. 1990, Bausch&Duke 1996) can be calculated to estimate the biophysical performance of agricultural crops. Other indices such as chlorophyll absorption fromratio index (CARI; Kim. Daughty. Chappelle, &McMurtrey 1994) and photochemical reflectance index (PRI Gamon, Robert, Green 1995). CARI found at ratio of 550 and 770 nm reflectance is constant at the level regardless of the differences in chlorophyll concentrations PRI vanes at the leaf level with photosynthetic capacity, radiation -use efficiency, and vegetation type (Gamon, et. al. 1995)

To achicve this goal, high resolution spectrometer can be used to acquire crop spectra in order to estimate above vegctation indices in relation to crop stress and vitality. Potentially, the use of spectrometers to measure the reflected radiation of vegctation offers new opportunities to estimate important carbohydrates of plants (Elvidge 1990). Specific absorption features caused by these compounds may also be found when moving such a spectrometer into an acroplane or even satellite and using it as asan imaging remote sensing technique (Goetz 1991) The demonstrated condition, d-cdgemoving thisrelationship between vegetation index mcasures and crop hyperspectral data can be used to provide useful information for crop management In order to analysis of hyperspectral data to be of direct, practical use in tactical management, however, it is necessary to cstablish a relationship between hyperspectral data and measures of crop status recorded directly on the ground. In this paper, the potential of imaging spectrometry for cotton crop under different 'stress leve! due to soil conditions is evaluated by studying the information contained in imaging spectrometer data. Analysis of red-edge ratio, CAI, NDVI, NVI, CARI and PRI was performed. These could result into a sclection of the most significant parts of the electromagnetic spectrum for cotton crop. It will also show whether information about plant biochemistry can be obtained and whether the red-edge is a significant region The objective of this rescarch was to determine the vegetation index values of cotton crop grown under difference soil fertility rates by evaluating hy perspectral data. In order to achieve a controlled range of sources and levels of plant stress due to fertility deficiency, we acquired spectral data of cotton crops grown under different soil conditions to replicate the different of fertility rates in the field This rescarch is also part ongoing validation of Compact High ' Resolution Imaging Spectrometer/Project Autonomy for (CRHIS/PROBA) campaign launched in orbit in October 2001 to monitor growing On-Board cvele of cotton crop at Colly cotton, Tuynam New South Wales.

METHODS

Growing test at glasshouse at University of New South Wales was carried out during growing season 2002/2003. Five varieties (Sicot 189, Siokra VI6. Delta Diamond. Delta Pearl, Dela Opal) of cotton crop under four types of soil ferulity rate were tested with level of water given was 455 millimeter during growing scason. This water dosage is equal to 650 millimeter rainfall for cotton growing area at Colly Cotton, Collenerebni in New South Wales Australia Base mixed-soils consist of three components, river sand, organic-rich soil taken South West area, and clay-rich soil taken from Nort West area of New South Wales were used in this experiment

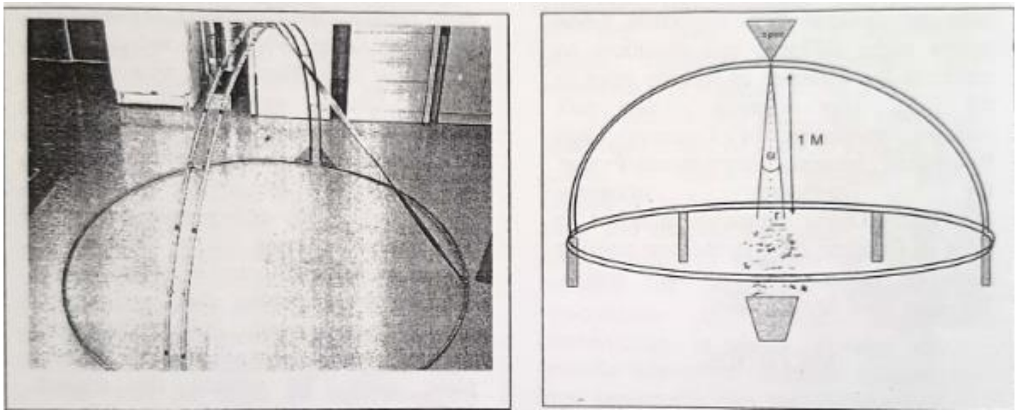
This mixed soil combination meet the soil requirement for cotton growing in with cotton needs rich-organic and clay soil (Cotton Australia 2001) A lot of the cotton grown in Australia is grown on cracking self-mulching clay and sandy soil (Cotton Australia 2001) Clay soi also has many nutrients that the cotton plant needs. To achieve the desired fertility rates, we mised with different percentage of three components, sand soils and levels of fertlizers added to cach soil see Table 1.

Tabel 1 Composition of soil fertility rate

No.	Mixed soil name	Symbol	Combination of sand, rich-organic matter soil, and rich-clay soil (%)
1.	Low	S0	60:20:20
2.	Moderate	S1	40:30:30
3.	Fertile	S2	20:40:40 + standard fertilizer (NPK)
4.	Very fertile	S3	20:40:40 + standard fertilizer (NPK) + micronutrient

$$\mathrm{r} = h * \tan\left(\frac{\alpha}{2} * \frac{\pi}{180}\right) \ldots\ldots\ldots\ldots.. (1)$$
$$A = \pi * r^2 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where r is the radius of field of vicw, height of equipment to the target, a is angle of view of the devise, and A is total area field of view to the target To compare among different fertility rate effect on appearance of cotton with the experimental spectroradiometer, measurements were made every 10 replica per pot per treatment These measurements were averaged to one spectral curve for each pot cxperiment. The calculation resulted in four spectral curves; very fertile, fertile, medium and low nutrient content of soil respectively This intermediate result was used to appoint and evaluate vegetation indices. Calculation of spectra values were focused on six aspects of indices: red- edge ratio (Gitelson &Merzylak 1996), CAI index (Oppelt & Mauser 2001a and b)NDVI (Tucker 1979) and NVI values (Takebe et al. 1990, Bausch & Duke 1996). The index of Gitelson & Merzylak 1996). The index of Gitelson & Merzylak(1996) shown in equation 3 was modified using 752 and 690 instead of 750 and 700 originally used nanometer of wavelength for such calculation for cotton crop. In this “red edge” ratio between 752 and 690 shows the vitality of a plant.



A B

Figure 1 Goniometer-like to acquaire spectra of cotton

Note : (A) Metal based and moveable pin on top (not shown) of Goniometer. (B) model show how to acquire spectra

$$red_{edge}ratio = \frac{\mathrm{R752}}{\mathrm{R690}} \ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

Where R752 reflectance value at 752 nm (%), R690 reflectance value at 690 nm (%).

The Corophyll-Absorptions-Integral (CAI) index derives the chlorophyll content by measuring the area between a straight line connecting two points of the red edge and the curve of the red edge itself. Therefore, it is an approach on the basis of a spectral envelope measurement (Oppelt & Mauser 200la and b). To fit to the spectral bands of the ASD radiometer,approach the CAl was modified as follows (sce equation 4 and 5).

$$mCAI = A - \int_{R552}^{R752} f \qquad (4)$$

Where A area of the trapeze between R552 and R752, f reflectance curve.

Therefore, the mCAI value was calculated as follow:

$$mCAI = \frac{(R552+R752)}{2}\, x$$
$$\text{(752-552)-sum}\sum_{R552}^{R752} Rx1.579 \qquad (5)$$

The modified CAl (mCAl) calculates the arca above the spectral curve between 552 nm (green peak) and 752 nm (compare Figure 2). The mathematic approach is to calculate the arce of the trapcze (A) between 552 nm and 752 nm and subtract it with the integral of the spectral curve between the same spectral values This calculated index also stands for the vitality and health of cotton plant under different fertilizer deficiently.

Calculation of each spectral value for different soil fertilizer rate was done by averaging all varicty spectra for each treatment, mean values. Therefore the spectra represent of averaged value of all verities.

The ratio of 550 and 770 nm reflectance to be constant at the level regardless of the differences in chlorophyll concentrations, and defined a chlorophyll absorption ratio index (CARI, Kim et al,. 1994). To estimate the variation within this range wavelength reflectance, the chlorophyll absorption band at 670 nm can be used to predict the CARI ratio variations, therefore:

$$\mathrm{CARI} = \mathrm{CAR}\,\frac{\mathrm{R700}}{\mathrm{R670}} \qquad (6)$$

And photochemical reflectance index can be calculated based on the ratio reflectance R528 and R567 These two wavelength absorptions are considered the band where the chemical absorption occurred (Gamon et al 1995)

$$\mathrm{PRI} = \frac{\mathrm{R528-R567}}{\mathrm{R528+R527}} \quad (7)$$

The Nitrogen vegetation index (NVI) was calculated using ration NR and Green reflectance, therefore the NVI is defined (Takebe et al. 1990, Bausch & Duke, 1996)

$$\mathrm{NVI} = \frac{\mathrm{R762}}{\mathrm{R550}} \quad (8)$$

Figure 2 depicts the spectrum range where the vegelation indices can be estimated including Red egde. CAI NDVI, NDI, CARI and PRI.

RESULT AND DISCUSSION

The visualization result

Figure 3 shows pictures of different vigor of cotton and sequence different among soil fertilizer deficiently.

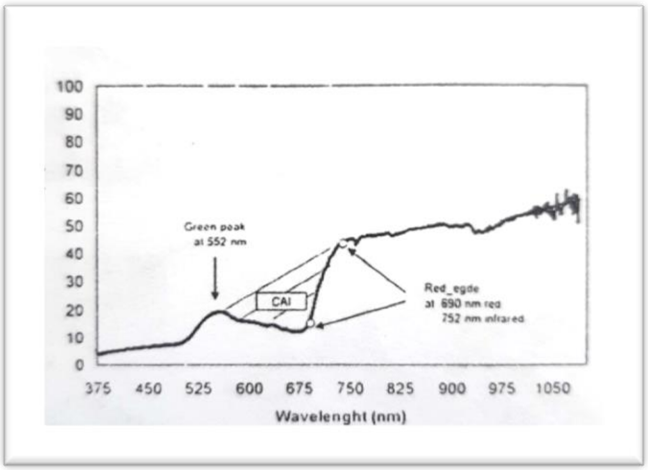


Figure 2. Graph showing spectral curve of healthy cotton crop with "red_edge" and green peak (the two points represent the wavelengths for the ratio, and green peak for calculating NVI, CAI and CARI (area above the curve)

As the pictures were taken in the end of November 2002, the difference among four experiment pots was clearly recognized (picture 3a and 3b) The green saturation and the performance of vegetation grow is clearly noticed The greenness among cotton crop under different soil fertility rate is recognizable (picture 3a, 3d, 3e and 3f). The greenness of the plant may be affected by the present of nutrient in the soil, especially the present of nitrogen in the soil. As cotton crops needs adequate nitrogen during growing cycle (Cotton Australia, 2001). the nitrogen deficiently may affect the vigor and greenness of cotton The mitrogen deficiently present here duc to for "low and medium soil categories lack of fertilizer added.

Vegetation index values results

The results show that hyperspectral analysis of cotton spectra grown at different soil fertility rates give different valucs spectrally of vegctation indices calculated. Hyperspectral measurements, shown in Figure 4, represent the average of various plants vigor and vitality undertheir different soil conditions which is represented in percentage of spectra against the wavelength. The reflectance curves of "healthy' cotton crops are characterized througl: high reflectance at red-edge position.Meanwhile lo reflectance value is clearly recognized for low and medium fertility rate for low reflectance at red-edge position. The "green peak" and the high reflectance in the near infrared portion of the spectrum are also visible Healthy' plants show nearly all the same reflectance curve for high and very high fertility rate because of their homogencous grew and vitality The reflection curves of low fertility rate of cotton crop are completcly different, with almost flat reflectance at red-cdge position. Their "spectral fingerprint (= spectral curve) nses from the blue portion of the spectrum to the Near Infrared ncarly continuous, except the part of the infrared shoulder, which shows also a lower slope and length in contrast to the other one.

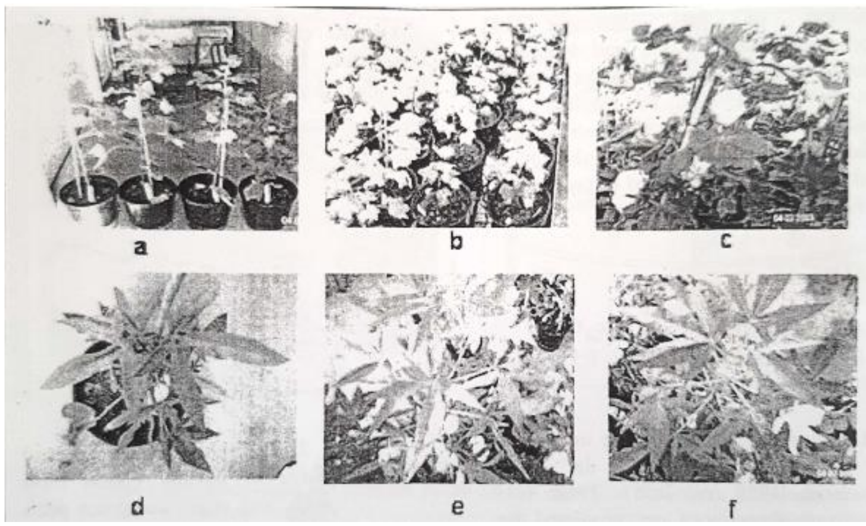


Figure 3. Cotton leaves appearance with different soil fertilizer rate
Note : (a) four types of very fertile, fertile, medium and low fertility rate at single pot (b) cotton leaves from very fertile to low, (c) leave under very fertile soil (d) low € fertile and (f) very fertile leave.

The reflectance and wavelength values of Figure 4 were used to calculate vegetation indices, which stand for the vitality and health of a plant. To point outfertile the difference and the spectral contrast among level of fertility condition of experiments, spectral and hyperspectralpoor vegetation indices formula were used to estimate the indices values.

Table 2 shows the fertile and very fertile soil condition give the higher value for all indices calculated, except for PRI value. Meanwhile without fertilizer and poor soil fertility give the lower values for given indices calculated.While the red edge, CAI and the CARI of healthy plants show high indices values Interestingly, in this simple calculation, the values on NDVI and PRI among the soil fertility conditions give almost the same values 0.99 to 100 and 008 to -0.11 respectively It is assuned that the NDVI valuc calculated is insignificant different among the soil condition due to the entire plants gown in this different soil conditions reflected of 'greenness' at the calculated values almost the same. This also can be assumed that the ratio value of red and near-infra red among soil treatments is the close range. It also notices that for photochemical index value, all plant grown in different soil will reflect the same value in term of photo chemical reflectance. This is due to photo chemical activities on this wave region is not affected by the different in soil fertility rate.

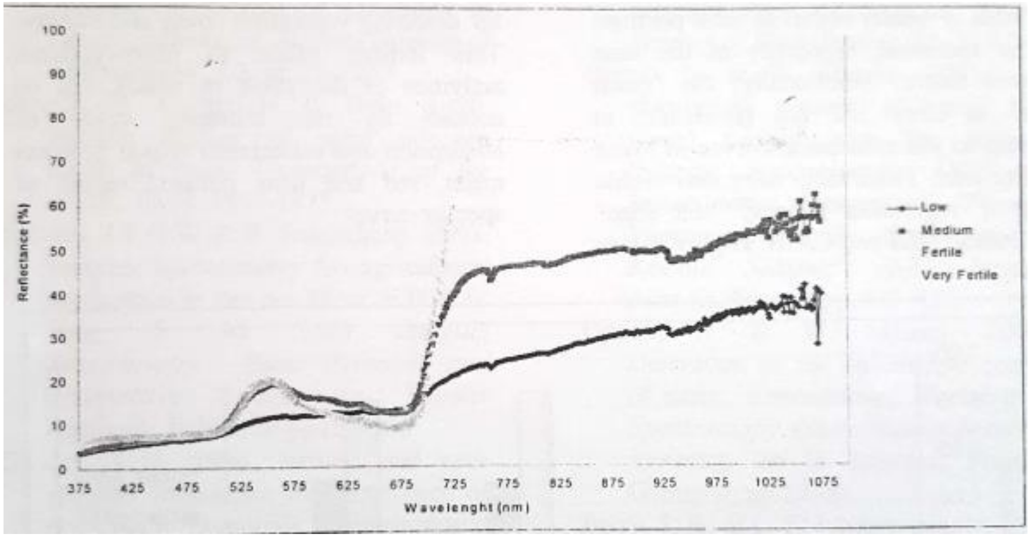


Figure 4. Averaged reflectance curves of cotton crop at different soil fertility rates

Tabel 2. Calculated value of Red_edge, CAI, NDVI, BDI, CARI, and PRI

Indices	Low	Medium	Fertile	Very Fertile
Red Edge	1.59	2.95	6.33	6.20
CAI/1000	0.51	2.15	4.47	4.60
NDVI	0.99	1.00	1.00	1.00
NVI	2.04	2.38	3.52	2.69
CARI	6.89	28.20	65.49	84.88
PRI	-0.09	-.011	-0.08	-010

The generated reflection curves showed a significant difference among cotton growth conditions. The reflection of healthy plants under soil fertilef condition in comparison to low fertility rate ones is clearly higher at most portions of the spectrum, especially at the near infrared sector. Additionally, the "green peak" at circa 552 nm is visible, inno contrast to the reflectance curves of lower fertility rate. These facts were also visible using 4 vegetation indices; "red edge" CAI-Index, NDI and CARI Higher values at the "red edge". CAI and CARI show a higher grade of plant vitality under very and fertile soil conditions. From this preliminary test of growing cotton can be used as spectra library reference for field spectra and image spectra of cotton in the field. Figure 5 represent the comparison of four most significant vegetation indices for detecting vegetation stress and vitality This indices relate to photosynthetic activities of the plant in which will be noticed by the changing value of and reflectance region between red and near infrared region of absorption green, spectra curve

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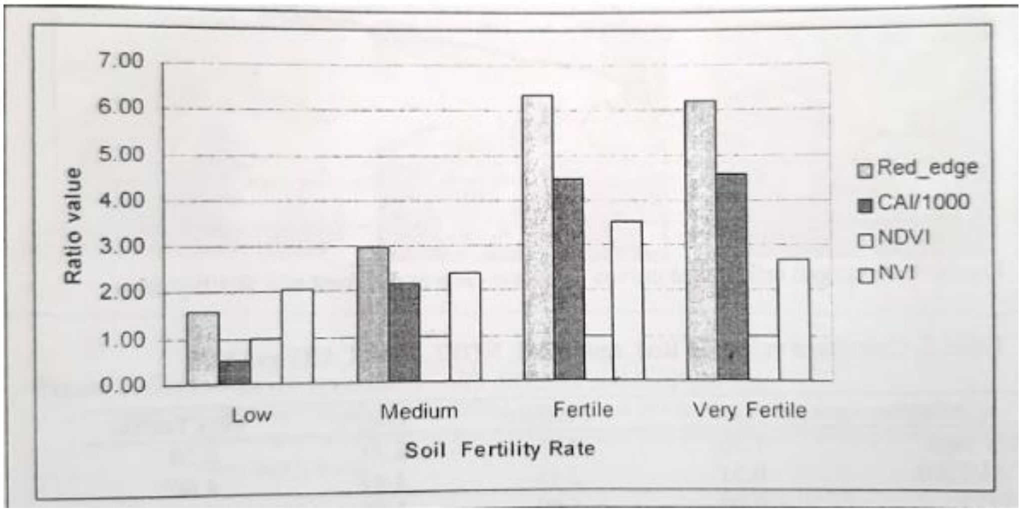

Figure 5: Graph of spectral and hyperspectral vegetation indices (“Red edge”, CAI, NDVI and NVI) to quantify the differences among cotton appearance under different soil fertility rate.

CONCLUSIONS

The performace of cotton crop under different soil ferulity rate is clearly identified. Cottn with low and medium categories show less "greenness" compared to the fertile and very fertile categories. The vegctation indices (red _edge. CAI Index, NDI, and CARI) of lower fertility rate presents in lower value compare to high fertility rate, except for NDVI, and PRI. Considering the presented results of the first data in the laboratory, the authors will intensify the field experiments in the field during 2003/2004 growing season. Additionally, multi-temporal space bome CHRIS/PROBA hyperspectral data analysis with evaluation against the laboratory and the ficld measurements will be used to develop a method spatial variation of soil fertility in the field.

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